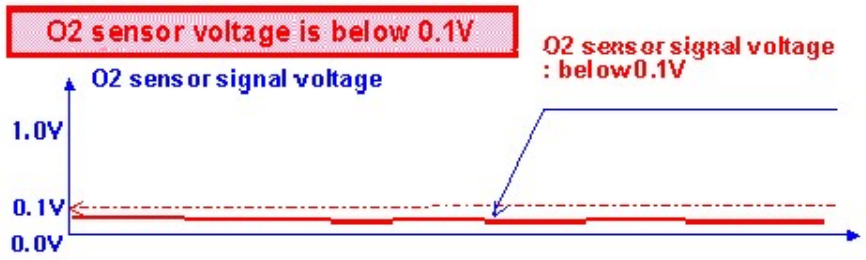
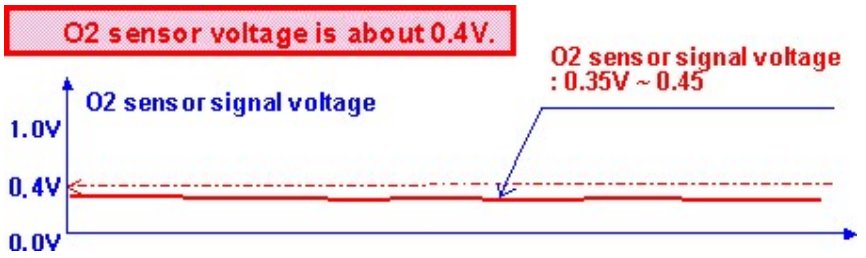
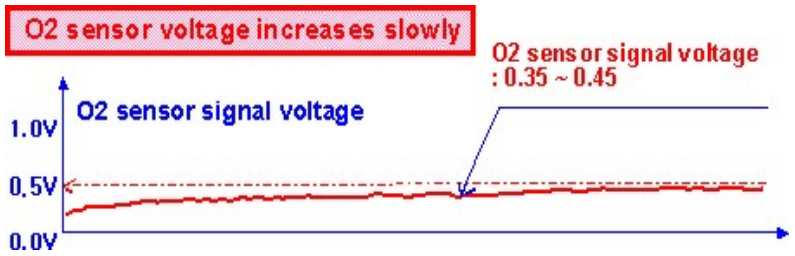
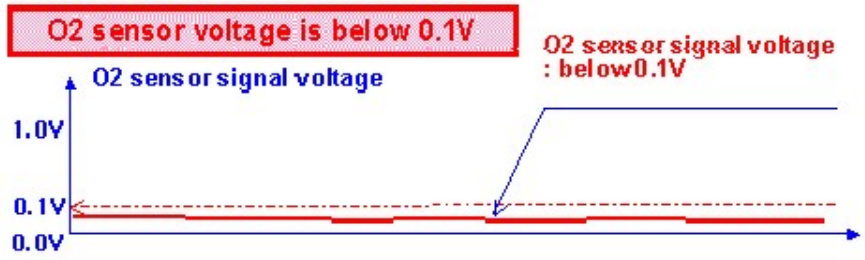
5. The signal analysis of O2 sensor

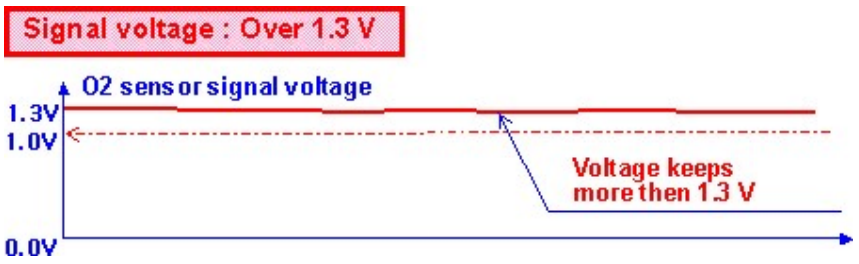
1. Troubles

Troubles	O2 sensor
1. Malfunction of O2 sensor	
Cause of trouble	1.1 General malfunction related to O2 sensor
Counter action	1.1 Healing by cause of trouble a.O2 sensor replace b.O2 sensor wiring circuit repair.
Engine state	Injection time control is unstable(Too rich or lean) and engine vibration or stall is occurred. In case of too rich injection control, poor acceleration is happened and color of exhaust gas is black. If ECU detect malfunction of O2 sensor, engine vibration and poor acceleration is disappeared.
Signal view	< Signal line short to ground case >  < Signal / Ground line open circuit or Abnormal O2 sensor case > 

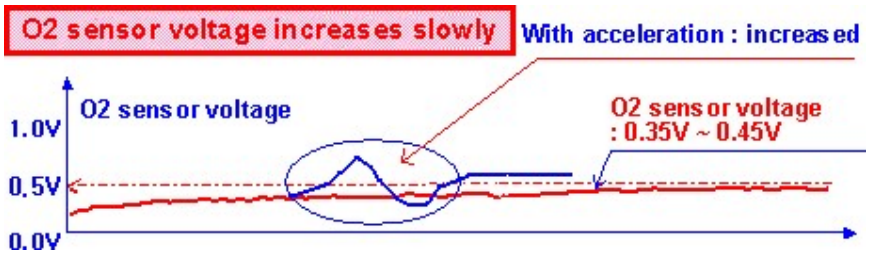
2. O2 sensor signal voltage is always constant (0.3~0.4[volt])	
Cause of trouble	Malfunction of O2 sensor or break of wiring circuit (Signal or Ground line) The exhaust gas temperature is too low
Counter action	Healing by cause of trouble a. O2 sensor replace b. O2 sensor wiring circuit repair Work acceleration pedal to increase exhaust gas temperature.
Engine state	Injection time control is unstable(Too rich or lean) and engine vibration or stall is occurred. In case of too rich injection control, poor acceleration is happened and color of exhaust gas is black. If ECU detect malfunction of O2 sensor, engine vibration and poor acceleration is disappeared.
Signal view	

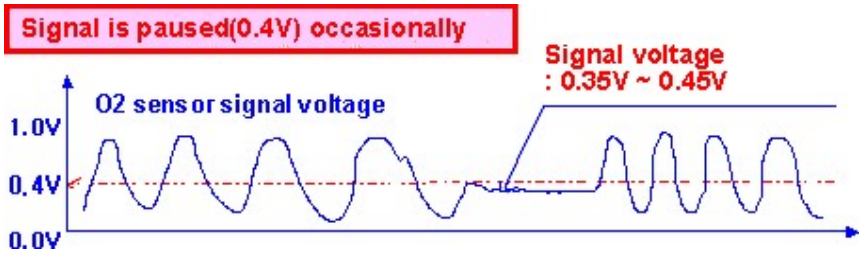
3. O2 sensor signal voltage is always low (Below 0.1[volt])	
Cause of trouble	3.1 O2 sensor signal line is shorted to ground
Counter action	3.1 O2 sensor signal line repair
Engine state	Injection time control is too rich and engine vibration or stall is occurred. In case of too rich injection control, poor acceleration is happened and color of exhaust gas is black. If ECU detect malfunction of O2 sensor, engine vibration and poor acceleration is disappeared.
Signal view	

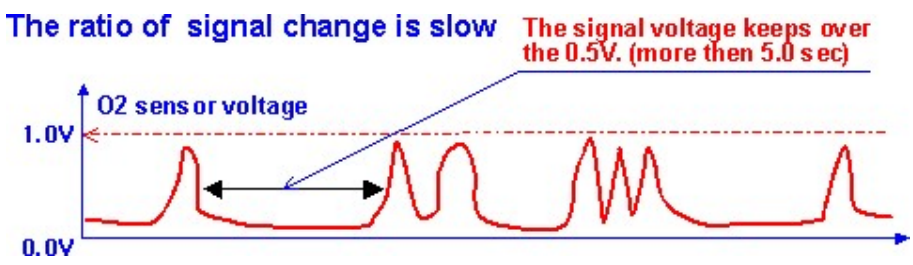
4. O2 sensor signal voltage is always high (Above 1.3[volt])

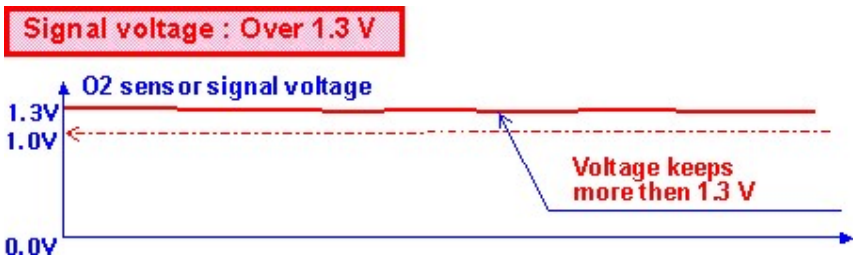
Cause of trouble	4.1 O2 sensor signal line is shorted to battery(12[volt]) or reference voltage(5[volt])
Counter action	4.1 O2 sensor wiring circuit repair
Engine state	Injection time control is too lean and engine vibration or stall is occurred. In case of too rich injection control, poor acceleration is happened and color of exhaust gas is black. If ECU detect malfunction of O2 sensor, engine vibration and poor acceleration is disappeared.
Signal view	

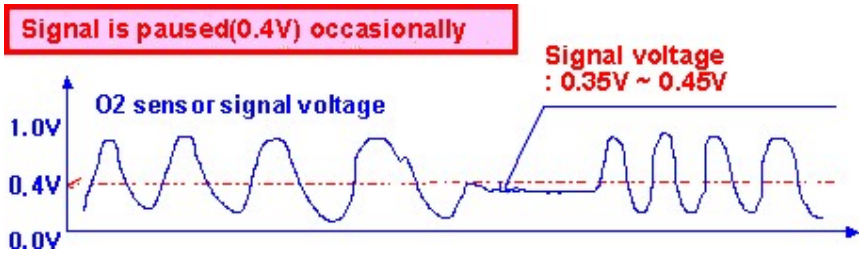
5. The response of O2 sensor signal voltage is too slow(O2 sensor light off time is too slow)

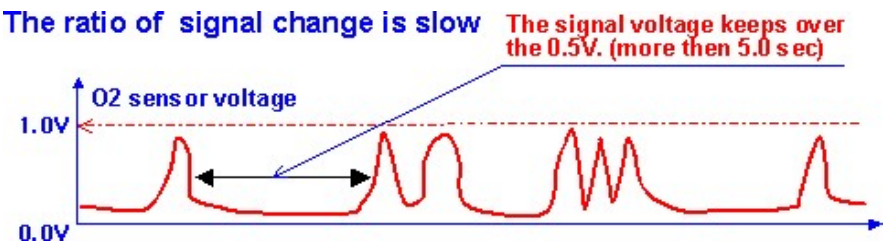
Cause of trouble	5.1 The exhaust gas temperature is too low.
Counter action	Work acceleration pedal and check signal a. Although working acceleration pedal, if response time O2 sensor signal is slow : Replace O2 sensor and check O2 sensor wiring. b. If O2 sensor signal is switched from below 0.15 to over 0.6[volt], O2 sensor is normal and it is due to low exhaust gas temperature. Therefore the sensor doesn't have to repair.
Engine state	Fuel is supplied too much before starting O2 sensor feedback control. It results in poor acceleration and black color of exhaust gas. This phenomenon is happened with long idle state or right after start. So, it is disappeared with O2 sensor feedback.
Signal view	

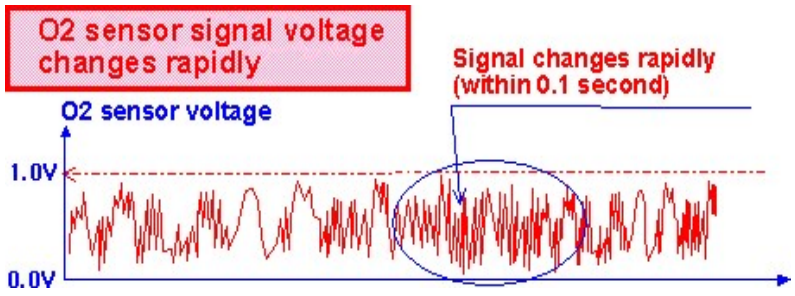
6. Occasionally, O2 sensor signal voltage is constant around 0.4 [volt]	
Cause of trouble	6.1 O2 sensor wiring(signal, ground line) is intermittently broken
Counter action	6.1 O2 sensor wiring circuit (especially connector) repair : Check signal line and connection of ground line. If it is not normal, repair it. <Reference> It may be occurred with low exhaust gas temperature, so work acceleration pedal.
Engine state	Fuel is supplied too much before starting O2 sensor feedback control. It results in poor acceleration, black color of exhaust gas and bad fuel economy.
Signal view	

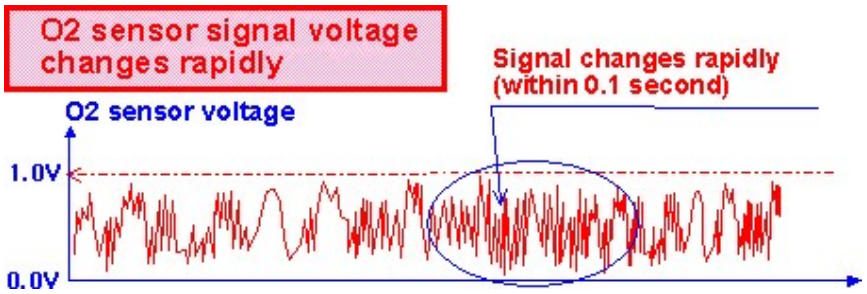
7. Occasionally,O2 sensor signal voltage is constant below 0.1[volt]	
Cause of trouble	Fuel Injection is not enough (Fuel injection control is lean) There is leakage on exhaust system(In front of O2 sensor position) O2 sensor signal line is intermittently shorted to ground (0[volt])
Counter action	Malfunction of fuel pump(Fuel pressure), Blocking of fuel supply line, Empty fuel tank, etc... The leakage on exhaust pipe must be sealed. Look for short to ground location of O2 sensor signal line and repair
Engine state	Fuel is supplied too much before starting O2 sensor feedback control. It results in poor acceleration, black color of exhaust gas and bad fuel economy.
Signal view	

8. Occasionally,O2 sensor signal voltage is constant above 1.3[volt]	
Cause of trouble	O2 sensor signal or ground line is intermittently shorted to battery. Check whether connector have moisture or not.
Counter action	O2 sensor wiring circuit repair : Look for short to battery location of O2 sensor signal or ground line and repair it. Remove moisture of connector
Engine state	Engine stall is occurred due to insufficient fuel supply(Intermittently). And knocking is happened when acceleration.
Signal view	

9. O2 sensor signal is abruptly stuck around 0.4[volt] with normal sensor .	
Cause of trouble	9.1 Exhaust gas temperature is low.
Counter action	Increase exhaust gas temperature with working acceleration pedal and check as below : a. If signal is fast switched from 0.1 to 0.9 : Normal b. If the signal voltage is constant around 0.4[volt] : Repair O2 sensor heater wiring : Signal or Ground line
Engine state	Fuel is supplied too much before starting O2 sensor feedback control. It results in poor acceleration, black color of exhaust gas and bad fuel economy.
Signal view	

10. Response time of signal voltage which is coming out above 0.6[volt] is slow (Longer than 5 [sec]) with feed back control	
Cause of trouble	10.1 Overflow of evaporative gas besides fuel injection : Abnormal opening of canister solenoid valve duty cycle / Overflow of oil gas from PCV valve (In case overfilling of engine oil)
Counter action	10.1 If the phenomena is disappeared after blocking area which overflow of evaporative gas is expected, it is due to overflow at the area. Therefore, repair the area.
Engine state	The surging is occurred with initial acceleration and then color of exhaust gas is black.
Signal view	

11. Additive correction of injection time is too small (Big negative value : below -0.8 [msec])	
Cause of trouble	11.1 Overflow of evaporative gas besides fuel injection with idle engine operating state : Canister solenoid valve opening with idle engine operating state / Overflow of oil gas from PCV valve (In case overfilling of engine oil)
Counter action	11.1 With idle engine state, if additive injection time correction is bigger and bigger after blocking area which overflow of evaporative gas is expected, it is due to overflow at the area. Therefore, repair it.
Engine state	Due to insufficient fuel supply before starting O2 sensor feedback after engine start, rough idle and vibration is occurred.
Signal view	

12 Response time of O2 sensor signal voltage is too fast (Faster than 0.1[sec])	
Cause of trouble	12.1 Air fuel ratio is not matched with stoichiometric cyliner by cylinder (Fuel distribution is poor)
Counter action	Injector is clogged : Cleaning injector The opening and closing phase of camshaft is not constant (Tappet gap of rocker arm is abnormal) : Low oil pressure or bad tappet Distribution of evaporative gas besides fuel injector is not matched each cylinders <Picture 4:Injector opening> : Change position of evaporative gas and PCV port It may be occurred due to bad fuel distribution from surge tank to each cylinder. With this case, repair is so difficult because surge tank design should be changed.
Engine state	Engine operation sound is rough. And in case of knock sensor equipped vehicle, knocking control retards ignition timing. It led to lack of power and bad fuel economy.
Signal view	

2. Field example

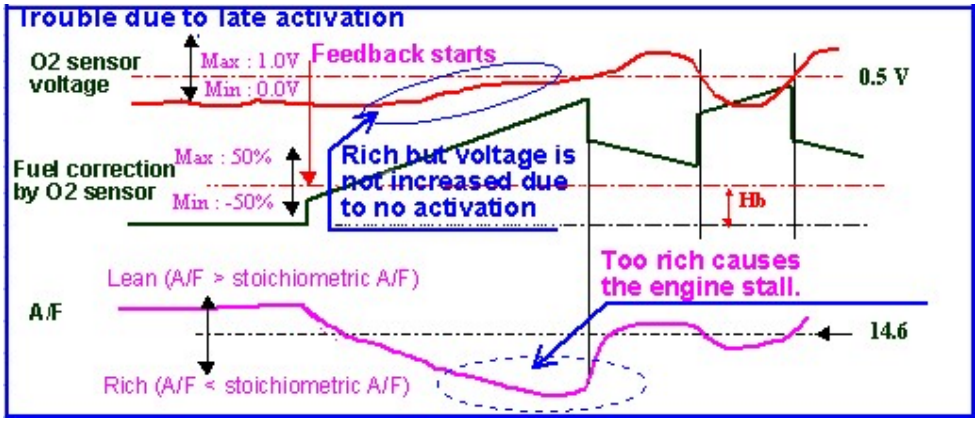
< Example 1 > The problem occurrence when start feedback before O2 sensor light-off

Vehicles : New sephia 1.5L SOHC/DOHC, Odometer : More than 28,000Km
Prince 2.0L SOHC, Odometer : 67,000Km
Espero 2.0L SOHC/DOHC, Odometer : 82,000Km.

Problem description : The acceleration is poor and RPM cycling is occurred in idle state. Engine stall is happened when working rapidly acceleration pedal with RPM cycling and if acceleration pedal is slowly worked, RPM is slowly increased and color of exhaust gas is black.

Cause : In case of non-heated O2 sensor type, ECU control fuel injection as starting feedback through O2 sensor before O2 sensor light-off. At the moment, O2 sensor signal stay from 0.40 to 0.47 [volt] because it is not reached light-off temperature, so ECU recognize lean fuel control and add injection time. It lead to too rich fuel control(A/F = 6 ~ 9) problem.

Signal measurement :



Explanation : This is happened by low exhaust gas temperature. Most of conventional vehicle, exhaust gas temperature is within from 280 to 340℃ range in idle state. Therefore it is due to low exhaust gas temperature (Minimum temperature for O2 sensor light-off : 370℃).

Enlargement of application : Even though this problem is not occurred with heated O2 sensor type, after replacing it, O2 sensor signal & ground line make originally connection with ECU and heater line connect with after main relay. After that replace new spark plug.
Reference : Fuel wetting of spark plug result in low ignition performance.

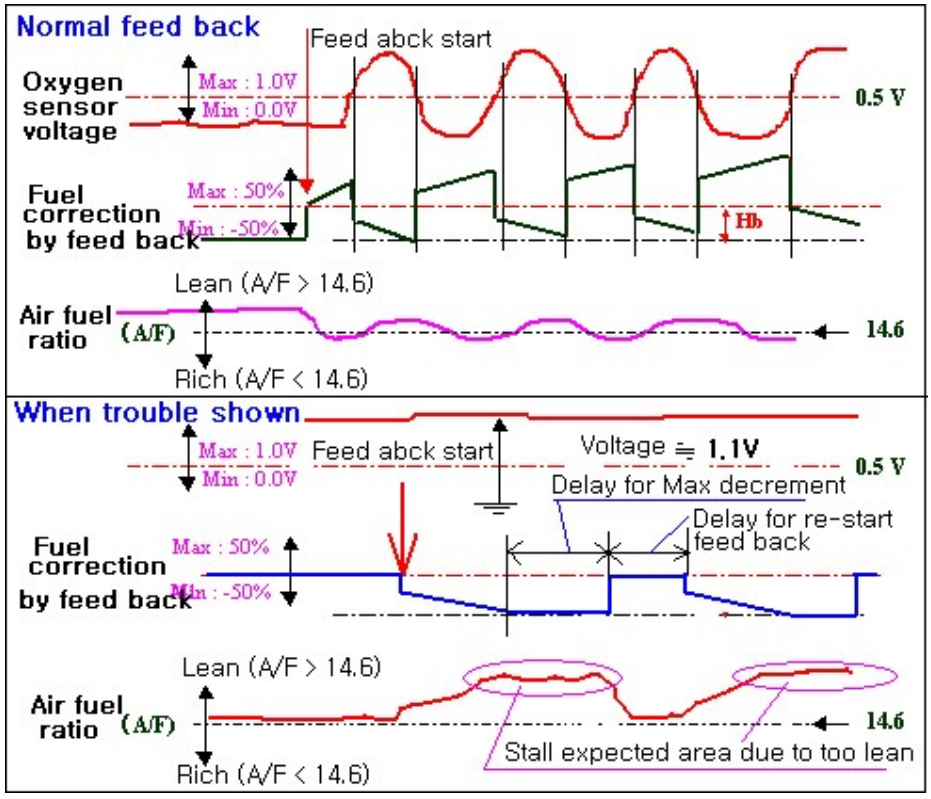
< Example 2 > The problem occurrence due to abnormal O2 sensor signal

Vehicles : Avante 1.5L DOHC, Odometer : 약 28,000Km

Problem description : Engine stall is occurred after severe RPM cycling as soon as engine start.(As soon as O2 sensor feedback start). At the moment, O2 sensor signal voltage stay 1.0 ~ 1.2 [volt].

Cause : O2 sensor signal line is short to battery due to moisture between connecting parts. Due to that, signal voltage is high and ECU reduce fuel injection(Max:33 or 50%) as starting feedback. Finally engine stall was occurred with lack of fuel.

Signal measurement :



Explanation : ECU detect malfunction of O2 sensor with signal voltage higher than 1.3 [volt]. Therefore this case is due to feedback without error detection.

Enlargement of application : Fuel control status that is supplied into engine is observed by O2 sensor signal measuring but fuel injection time adding(higher than 0.5volt) or deduction(less than 0.5volt) is only observed. In this case, although O2 sensor signal is high due to short to battery, we cannot distinguish whether actual fuel injection is much or less. But you have to expect that ECU reduce fuel injection with O2 sensor feedback.

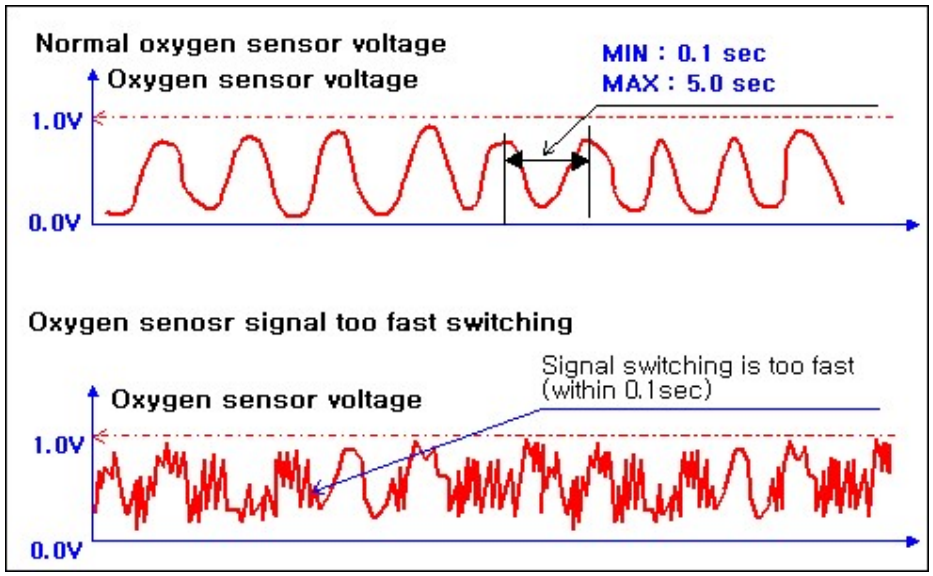
< Example 3 > Fuel injection status check through O2 sensor

Vehicles : Rio 1.5L DOHC, Odometer : 4,200Km

Problem description : O2 sensor signal is rapidly switched and engine vibration is occurred. Due to knocking detection, performance and fuel economy is poor.

Cause : The intake valve closing and opening was not exact due to number 3 cylinder hydro tappet trouble. It result in lack of mass air flow in corresponding cylinder and A/F of 3 cylinder is rich

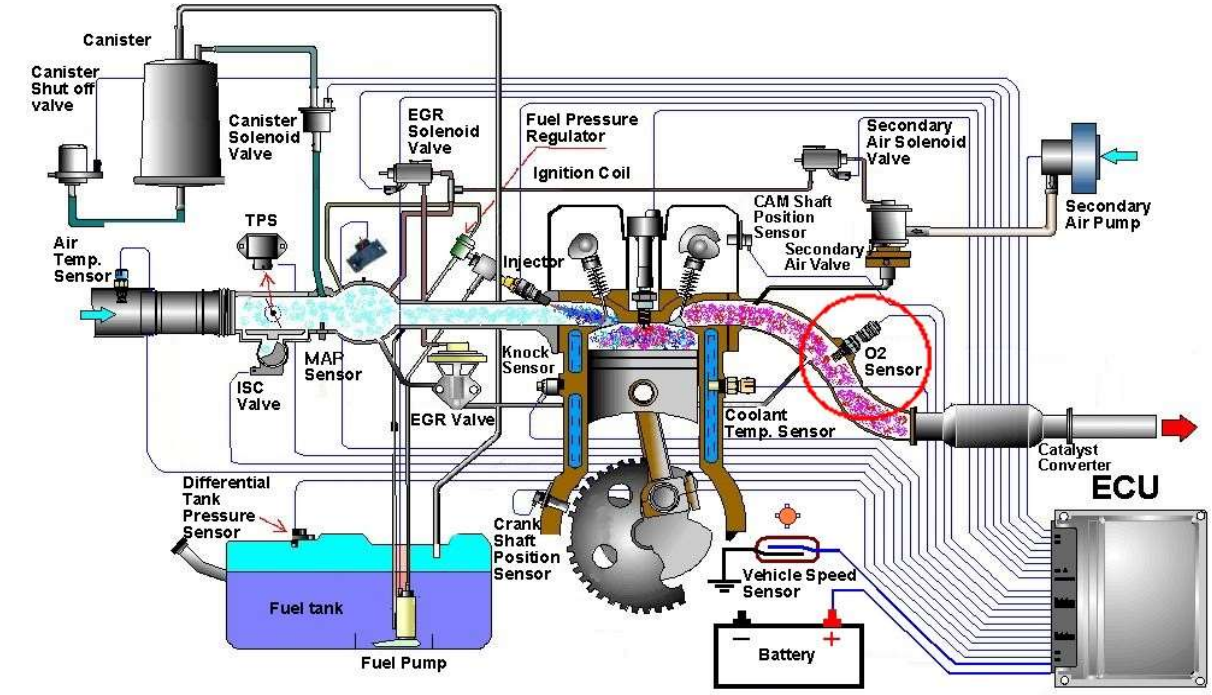
Signal measurement :

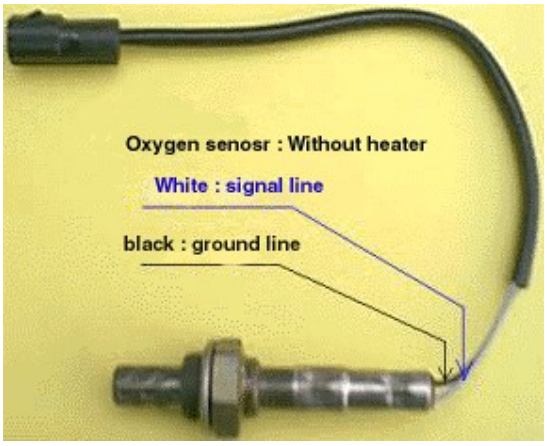


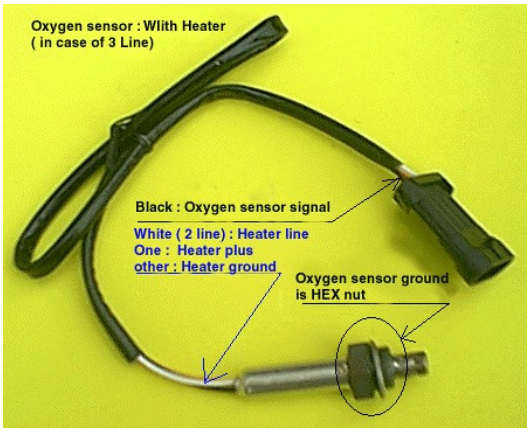
Explanation : A/F between each cylinders is different(3 cylinder is rich), so engine vibration is occurred and ignition is retarded with knocking detection. It leads to bad performance and fuel economy.

Enlargement of application : Fuel control status that is supplied into engine is observed by O2 sensor signal measuring. Thus you can estimate that fuel injection time is lack(higher than 0.5volt) or over(less than 0.5volt). With rapidly O2 sensor signal switching, you can estimate “fuel status that is supplied into combustion chamber” (Ex: Misfire in combustion chamber, A/F difference between cylinders : injector clogging, fuel gas overflow from purge valve).

3. Location of oxygen sensor







4. Check method

Explain the checking Method and Diagnosis of trouble

Preparation

Oxygen sensor signal voltage (between 0 to 5volt) can be going well to be heated by exhaust gas (over370degC) though Oxygen sensor has heater. And you can diagnose the function of oxygen sensor exactly to be feedback. Check the troubles as following procedure.

1. Keep on stepping on the accelerator pedal lasting the engine revolution over 2000rpm during 2 minutes.
2. Make the Oxygen sensor feedback: If heater was not installed, Feedback condition is difficult at vehicle stop. Thus must drive over 5 minutes in speed over 60Km/H generally.

< Reference > After making the feedback, signal must be checked on condition of engine running not key off.

3. Measure the Oxygen sensor signal with connecting the HI-Scan or Oscilloscope.

< Reference > It prefers not to use Multimeter because it is difficult to show the fast signal changing.

< Reference > In case of connecting the Auto Scanner, there is no need additional trouble checking because It analyses and diagnoses the troubles automatically.

1. 1. Find and connect the signal and ground line with referencing the wiring diagram.
2. 2. After measuring the signal, compare the measured signal with Normal signal.
   (1) Check whether the signal switches (up and down) too fast (within 0.1 second) or slow (over 5 second)
   (2) It prefers to use the Scanner in the same time.
3. Check the followings with connecting the scanner after making the engine fully warmed-up and keeping Idling above 10 minutes.

< Checking items>

(1) check that the additive adaptation value (fuel adaptation in IDLE) is in normal range(within ±0.8 mmsec)

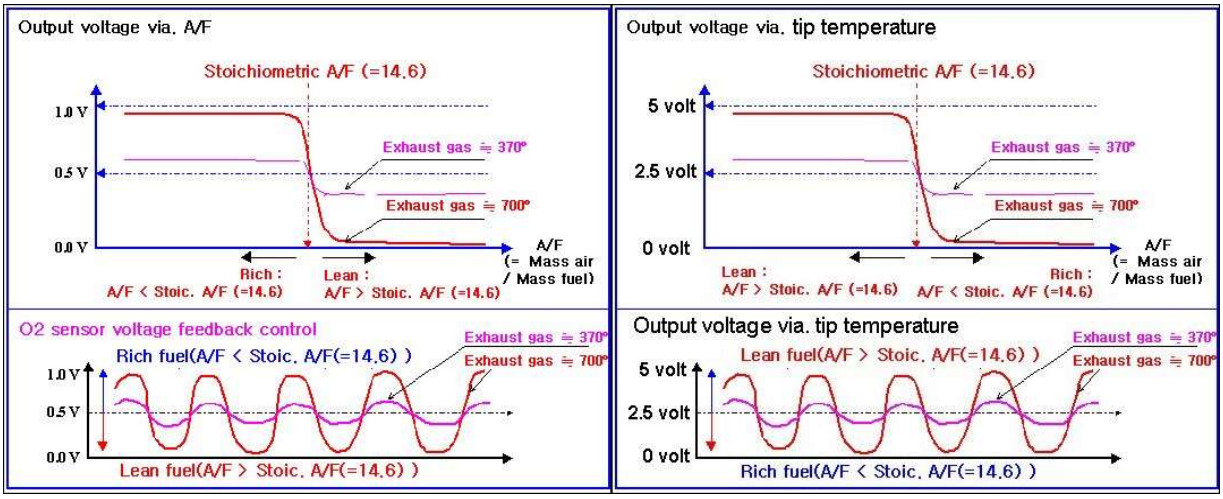
(2) check that the multiplicative adaptation is in normal range(within ±15%) after driving(over 3 days)

5. Wave anlaysis

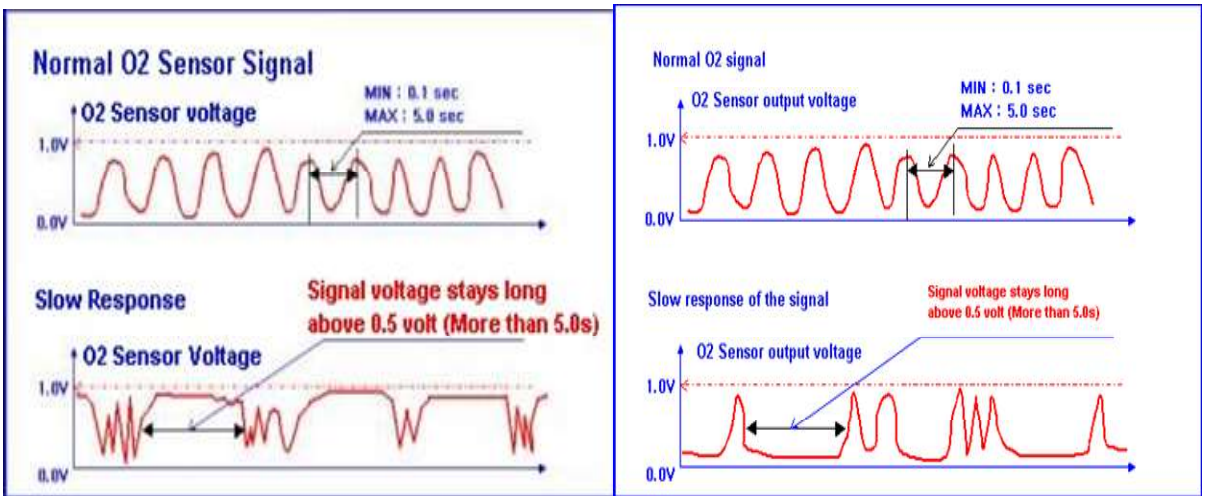
Explanation is for zirconium O2 sensor. In case of Titanium O2 sensor, the voltage range is 0~5V and signal is opposition.

When oxygen sensor signal is measured, the output voltage depends on exhaust gas temperature even though heater is existed. That is, the higher exhaust gas temperature is the higher oxygen sensor output voltage. So O2 sensor signal check should be done after acceleration. And if signal is moving(up/down), the sensor status is considering as normal and then it's required the analysis of fuel delivery system of combustion chamber.

The output voltage of oxygen sensor is as follows.



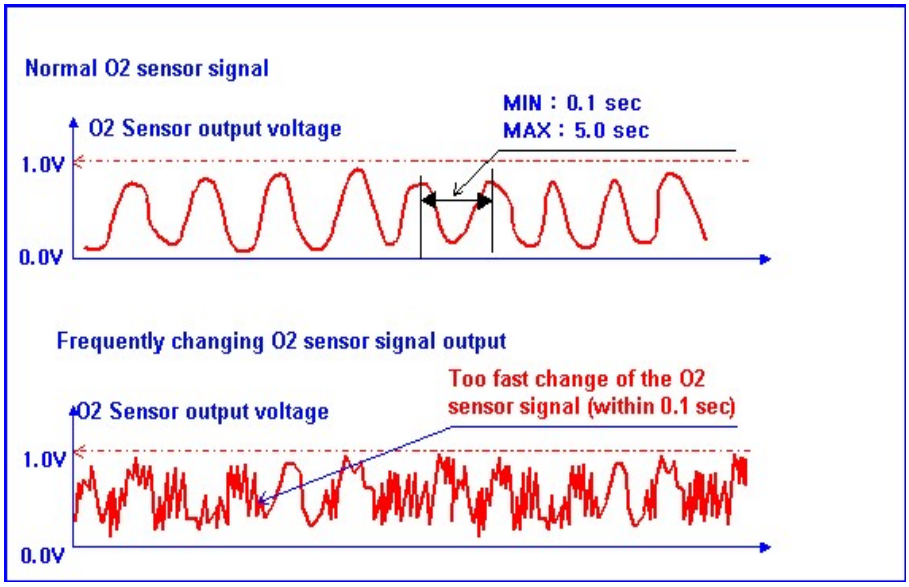
<Oxygen sensor signal voltage : Zirconium(left), Titanium(right) >



< Too rich fuel (left) / Too lean fuel(right) >

If cylinder fuel distribution is bad, the signal shape is unstable(fast switching). It means sensor is normal but fuel system is somewhere wrong.

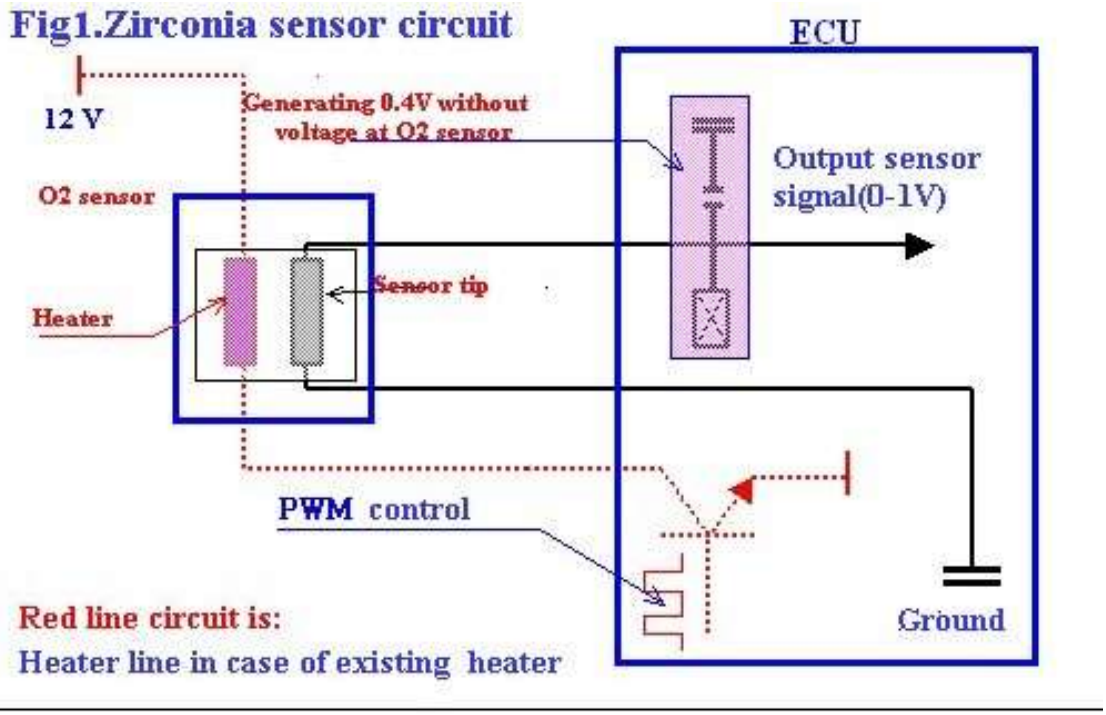
< In case fuel distribution is not good

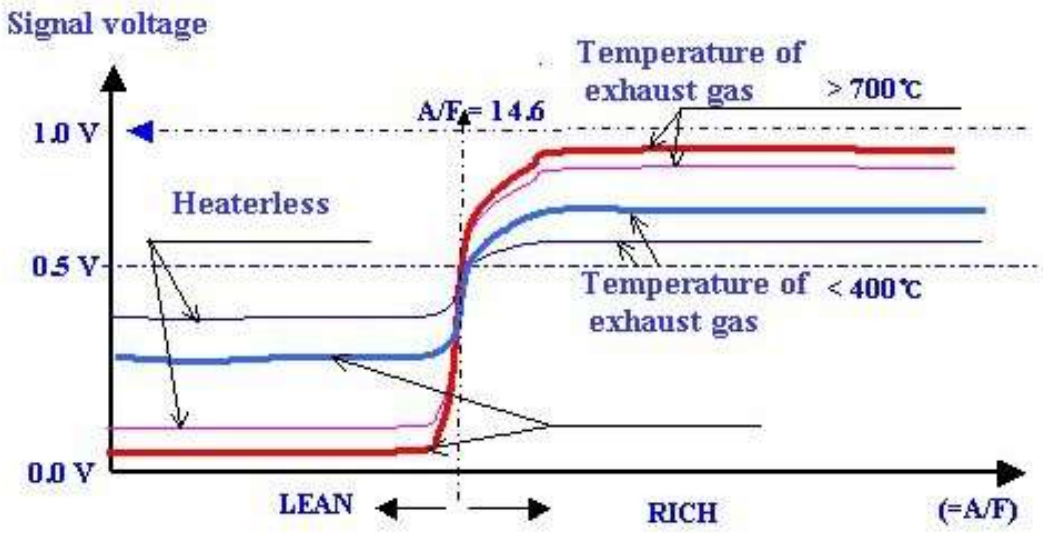


6. General

Zirconium oxygen sensor

Oxygen sensor is located in front of three way catalytic converter and made by zirconia (ZrO2), which generate electric pressure according to the density of oxygen. It is also determined by this sensor whether supplied fuel quantity is more required than fuel quantity (stoichiometric ratio, air/furl = 14.6) or not. Sensing part is located within exhaust manifold. In case much oxygen is included within exhaust gas (Lean: case of little fuel supplied) sensor out put voltage is below 0.5V, otherwise (Rich: case of much fuel supplied) sensor out put is over 0.5V.

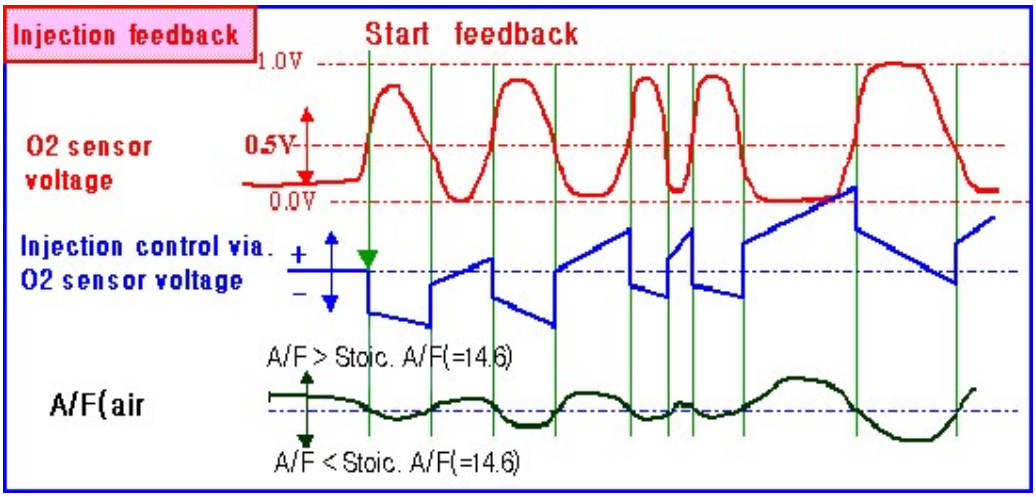




< Fig 1 : O2 sensor Zirconium --- SIEMENS system>

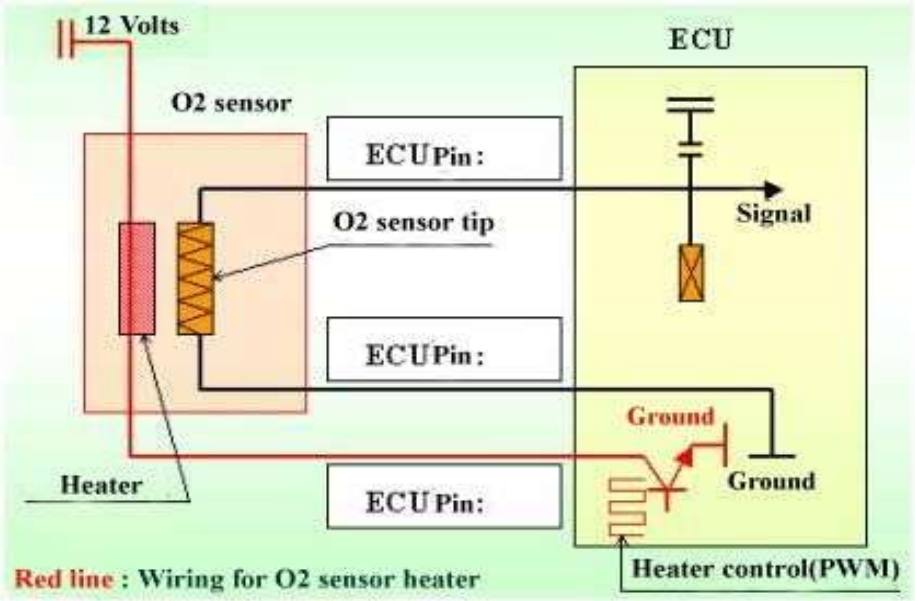
Zericonia must be fully warmed up (over 370°C) to get sensor out put voltage form 0.05V (case of little fuel supplied) to 0.95V(case of much fuel supplied), otherwise sensor output voltage is remained around 0.4V. To heat sensor tip part, heater is installed at the edge of oxygen sensor and heat oxygen sensor. Sensor voltage out put is remained around 0.4V, in case no heater is engaged or heater error is exist and then sensor is heated only by exhaust gas and exhaust gas temperature is too low.

< Reference > When oxygen sensor is not heated and out put voltage is not generated, sensor out put voltage is remained around 0.4V by ECU internal circuit. Otherwise, sensor out put voltage is generated from near 0V (In case little fuel is supplied) to 1V (In case of much fuel is supplied) according to the density of oxygen

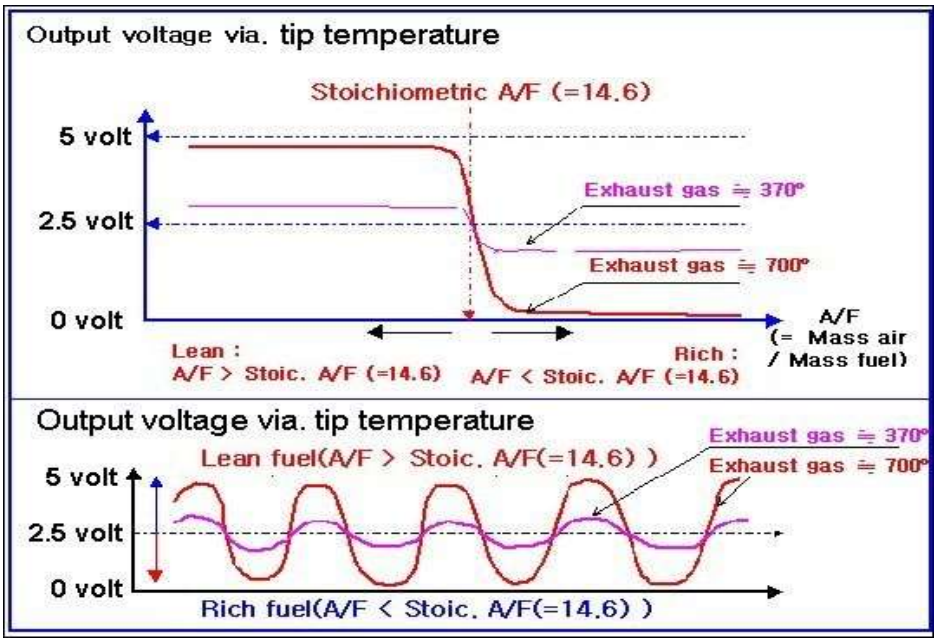


Titanium oxygen sensor

Titanium oxygen sensor is located in front of three way catalytic converter and made by titanium (TiO2), which changes resistance pressure according to the density of oxygen. It is also determined by this sensor whether supplied fuel quantity is more required than fuel quantity (stoichiometric ratio, air/furl = 14.6) or not. This is supplied 5V power from ECU and 0.5 ~ 4.7V out put voltage is generated according to the density of oxygen. Sensing part is located within exhaust manifold. In case much oxygen is included within exhaust gas (Lean: case of little fuel supplied) sensor out put voltage is over 2.5V, otherwise (Rich: case of much fuel supplied) sensor out put is below 2.5V.



< Fig. 2 : Circuit of Titania O2 sensor -----SIEMENS system >



This oxygen sensor determines only fuel lean or rich state compared with stoichiometric. ECU do feed back control (In case of below 2.5V injection quantity is decreased otherwise increased) by means of oxygen sensor out put voltage and maintain stiochiometric, and this feed back control can increase catalyst efficiency.

7. Principle (Algorithm) introduction

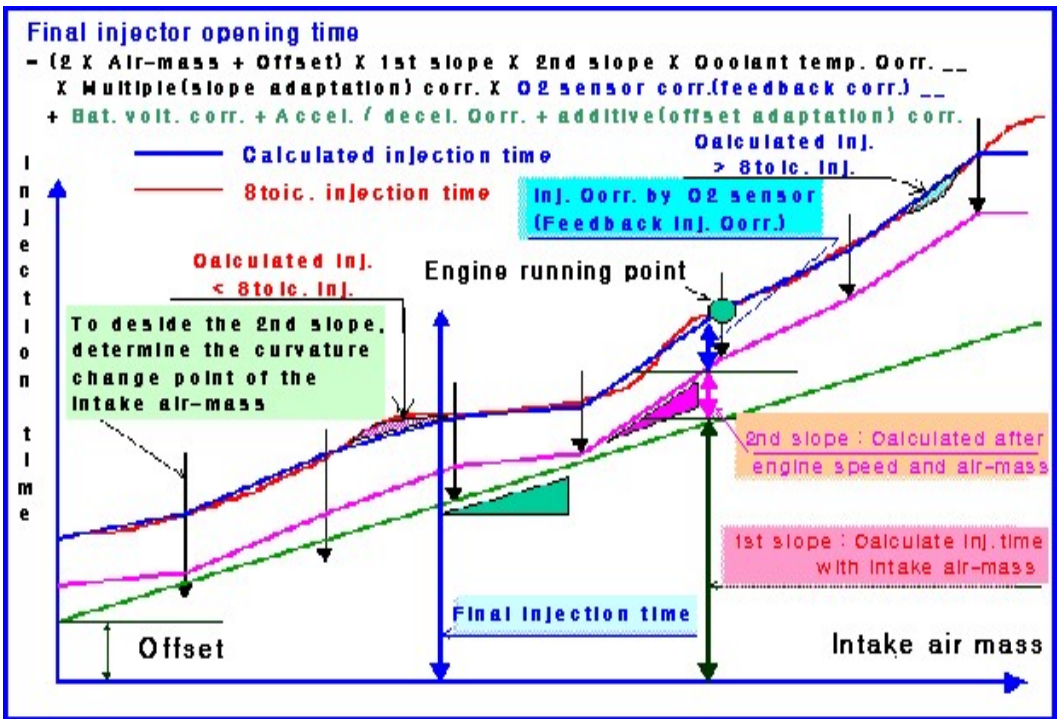
Some problems on fuel feedback control cause by oxygen sensor is difficult to solve it with only sensor signal. So, I'd like to introduce the algorithm.

This algorithm may be little bit difficult to understand but the problem caused by adaptation is one of the problem that hardly can find the root cause in the file or A/S center.

First of all I'd like to ask you to understand the principle first before you solve the problem. Because this is not an easy problem, which even A/S from carmaker can not solve, and if you understand the principle then you can solve the problem that other can not do.

Calculation of injection time

<Figure 3: injection time calculation >



Injector opening time decides fuel amount. This time is decided after calculation of required fuel amount to consume measured air quantity from MAF(Mass Air Flow) sensor or MAP(Manifold Air Pressure)sensor. And specific correction factor is need to compensate various engine operating conditions.

1) Coolant temperature compensation.

Injection time is increased depend on coolant temperature because of following reason ;

First: To compensate fuel film (wall film) in the intake.

If coolant temperature is cold then the fuel injected in the intake runner will from a film on not only the valve but also the intake runner. Because of this fuel film, additional fuel have to be provided to compensate it

Second: To compensate non vaporized fuel.

In case of low coolant temperature, injected fuel is not vaporized and burned in the cylinder. As actual burnt fuel compared to air quantity is smaller in that case, more flue have to be provided.

Third : To make good engine operation.

Recently emission regulation is getting strong, so that only above two compensation is used for injection correction above 20°C (For US export -Over 5℃) and provide little bit more fuel than stoichiometric air fuel ratio to get easier engine operation at below 20°C. Especially make reasonable engine operation below-10°C.

For your reference, following table is target air fuel ratio made by me when I worked for electric control unit development.

Coolant	Below - 25℃	- 25 □ -10℃	- 10 □ - 0℃	0 □ 10℃	Above 20℃
Air fuel ratio	10 - 12	12.5 - 13.5	13.0 - 14.0	13.5 - 14.5	14.6

<For reference, ECU use following temperature in case of coolant sensor error >

a) Switch on cooling fan always,

b) If intake temperature is below 20°C then set same temperature for coolant and increase it by 1°C per every 5sec until 90°C and fix it to 90°C

c) If intake temperature is over 20℃ then set 20°C for coolant and increase it by 1°C per every 5sec until 90°C and fix it to 90°C

d) In case of intake air temperature sensor failure, set 20°C for coolant and increase it by 1°C per every 5sec until 90°C and fix it to 90°C

As this data can be different by EMS(Engine Management System) maker or developer even with same EMS(Engine Management System, keep this information as an example.

2) Intake air temperature compensation

There are many case of no air temperature sensor with MAF(Mass Air Flow) sensor but it is necessary for MAP sensor. Because real air mass in the surge tank has relation not only with pressure but also temperature. As air mass is in inverse proportion to square root of air temperature, MAP is necessary. In case of MAF sensor, as it use changing of resistance by cooling of sensing part by air flow, amount of air flow is different by air temperature because of different cooling effect depend on air temperature. But there are also many cases that use air temperature sensor to get more precise control or to prevent pulsation.

Intake air temperature effect : Real air mass □ k * 1 / (Temp.)½

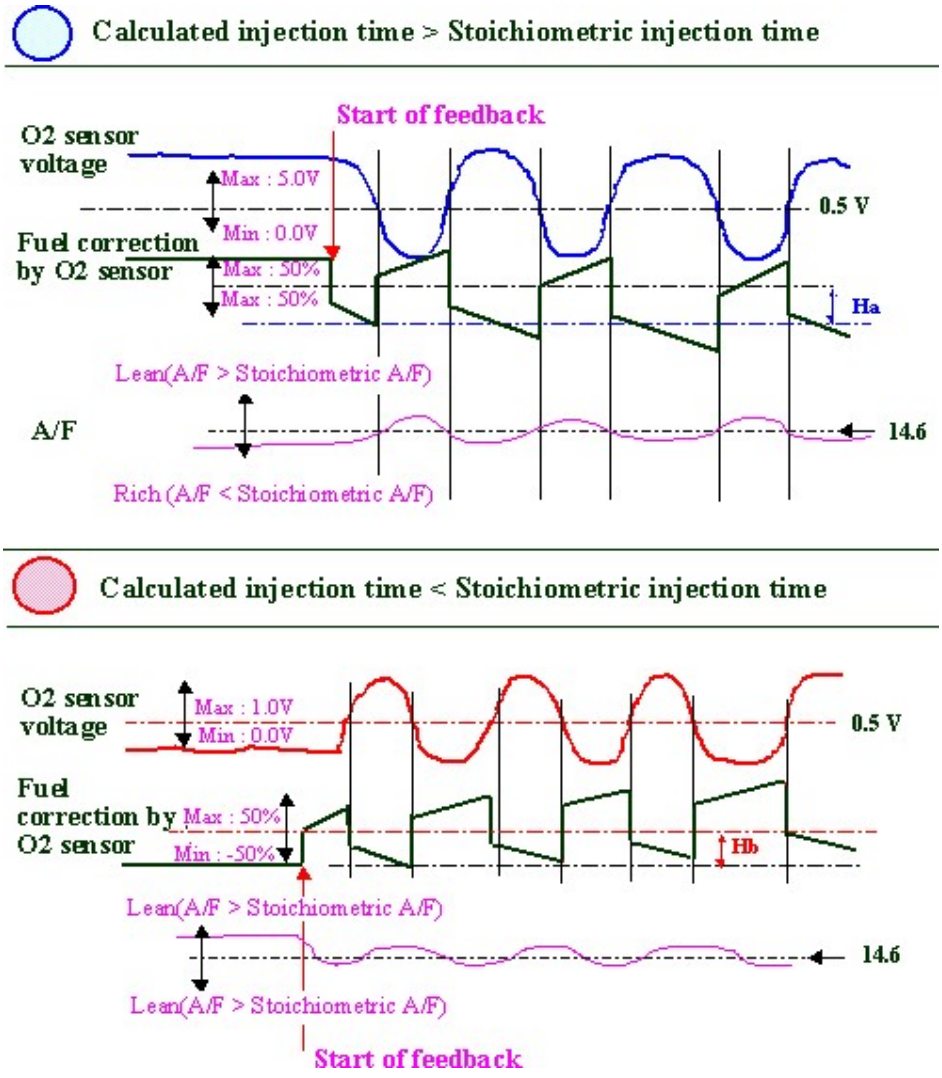
<For reference, ECU use following temperature with intake air temperature sensor error.>

There are two method for Siemens system.

a) Keep always 20℃(possible to change it but generally use this value)

b) I confirmed it but I did not use it (Because, there is no problem to use 20°C to start the engine.): If coolant temperature is below 20°C then set same temperature for intake air temperature and then increase it by 1°C per every 100sec until it reaches 20°C. If intake air temperature is over 20°C then keep 20°C.

3) Fuel compensation by oxygen sensor signal: Fuel is corrected by oxygen sensor signal.
If signal shows not enough fuel compare the stoichiometric ratio, then more fuel is provided or on contrary, it shows rich signal then less fuel is provided. And doing like this the average of provided fuel is close to stoichiometric air fuel ratio. This is directly linked to adaptation.

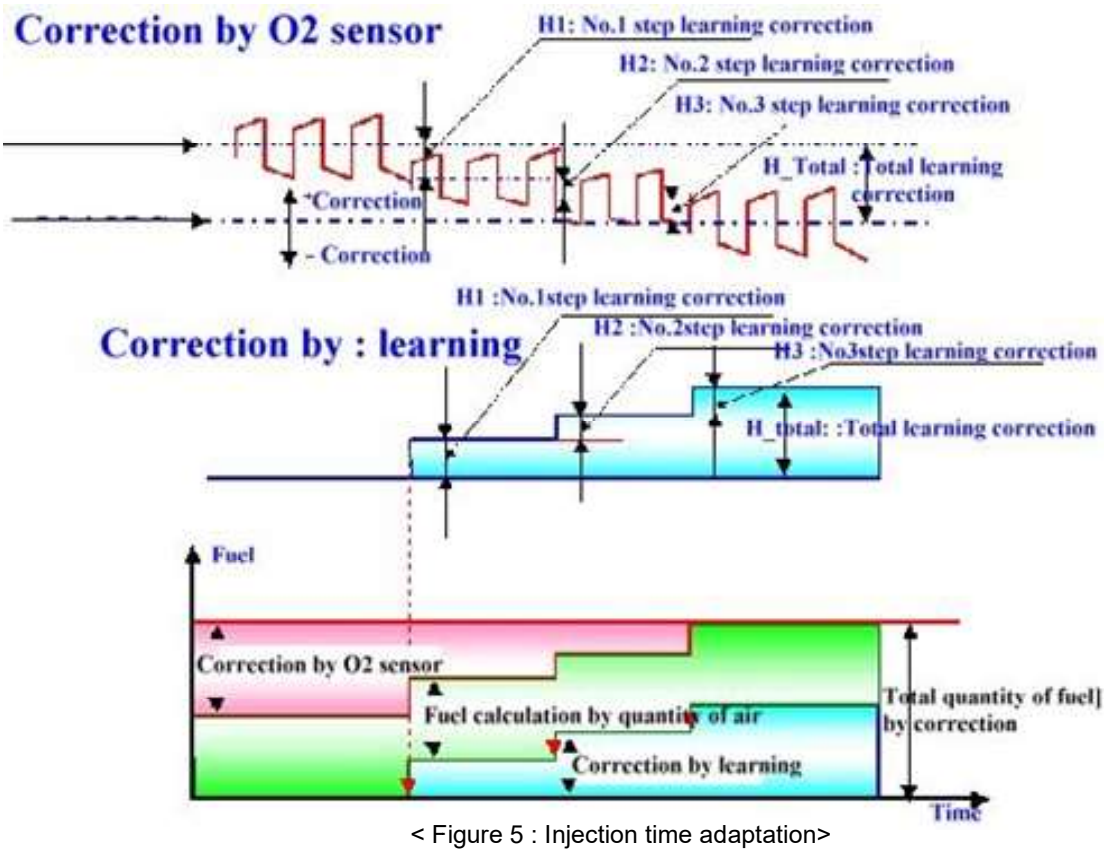


< Reference >

a) Stoichiometirc air fuel ratio : The air fuel ratio when air and fuel supplied to the engine is burned completely and oxidized to CO2 and H2O. Generally it is 14.5 – 14.,6 with gasoline engine and 15.2 with LPG engine.

b) Zirconia Oxygen sensor : if fuel is rich than stoichiometric ratio then over 0.5V or not below 0.5V(close to 0V).

c) Titania Oxygen sensor : if fuel is rich than stoichiometric ratio then below 2.5V(close to 0V) or not over 2.5V(close to 5V).



< Figure 5 : Injection time adaptation>

4) Fuel compensation by adaptation : This is to reduce the variation of each engines.

In case of that fuel correction is shifted to one side (always higher or lower than middle value), two adaptation values are used to calculate injection time to make fuel correction by oxygen sensor is located in the center.

a) Additive correction : Injection time calculation in idle is composed of additive term and multiple factor. As air flow in idle is too small, multiple factor has not so much effect on injection time correction. In the other hand, if change additive value, we can get large injection time changing rate. That's why we use additive term in idle.

(Injection time = air mass *other factors * multiple adaptation factor + other term + additive adaptation term)

And the correction method is If injection time correction by oxygen sensor is bigger than center value then this is the case that injection time is smaller than actual value. Therefore oxygen sensor correction can be set to center value by adding additive adaptation value into the injection time calculation. In reverse case, if oxygen sensor correction is lower than center value then additive adaptation value is subtracted from the injection time calculation to set oxygen sensor correction to center.

b) Multiple correction : Contrary to idle, in case of pushing in throttle pedal, air flow is bigger than idle and additive correction is too small to correct injection time. So, multiple factor is used to change injection time.

It is same as idle that multiple correction decrease with increasing of injection time correction of oxygen sensor or increase with decreasing of injection time correction of oxygen sensor

5) Other correction

a) Altitude correction : Measured air quantity by MAP or MAF sensor in the high altitude is lower than real air quantity to the cylinder due to low ambient pressure and low exhaust pressure. In order to compensate it, ambient pressure is checked before engine start or calculated when engine speed is low(below 2000rpm) with more than 70% of throttle opening by MAP sensor. As a reference, additional ambient pressure sensor can be used for MAF sensor or ambient pressure can be calculate by using engine speed, throttle opening and calculated air flow.

< Reference >

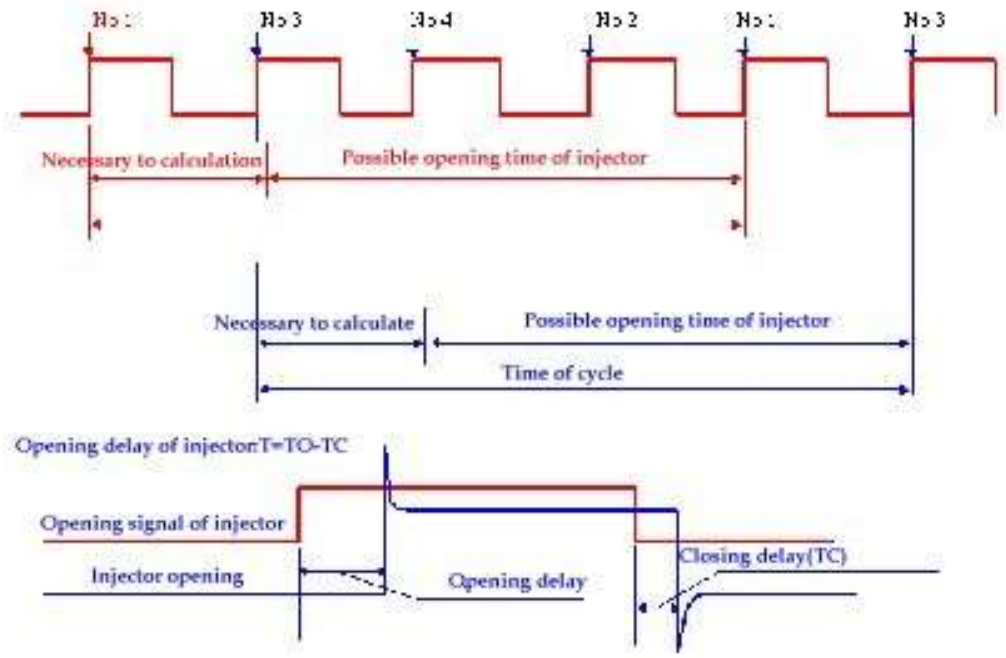
Most of people know that injection time correction is due to low air density in the high altitude. But this is not true, real purpose is to compensate different airflow (efficiency)due to low exhaust pressure by low ambient pressure and it depends on exhaust system.

b)Acceleration/deceleration correction : If there is sudden increase of air flow due to acceleration or turn on the Air conditioner, a lot of fuel is laid on the intake runner due to sudden decreasing of manifold under pressure to suck the fuel in to the cylinder. Therefore, lean spike is happened due to insufficient fuel compare to stoichiometric air fuel ratio. In order to compensate fuel laid on the wall (wall film), additional fuel is provided and this is acceleration enrichment. And contrary to this, if we release the throttle pedal from acceleration, fuel film on the intake inside sucked into the cylinder and decel compensation to reduce fuel is performed in this time. Generally, compensation is consists of two different correction. One is by pedal speed and the other one is by air flow. And engine speed and coolant temperature are used to calculate these two compensation values.

< Reference >

To provide more fuel to improve acceleration response is not wrong but basic purpose is to compensate wall film and accel improvement is cause by a side effect.

Specially, stoichiometric air fuel ratio at all operating point is required to correspond to current strong emission regulation.



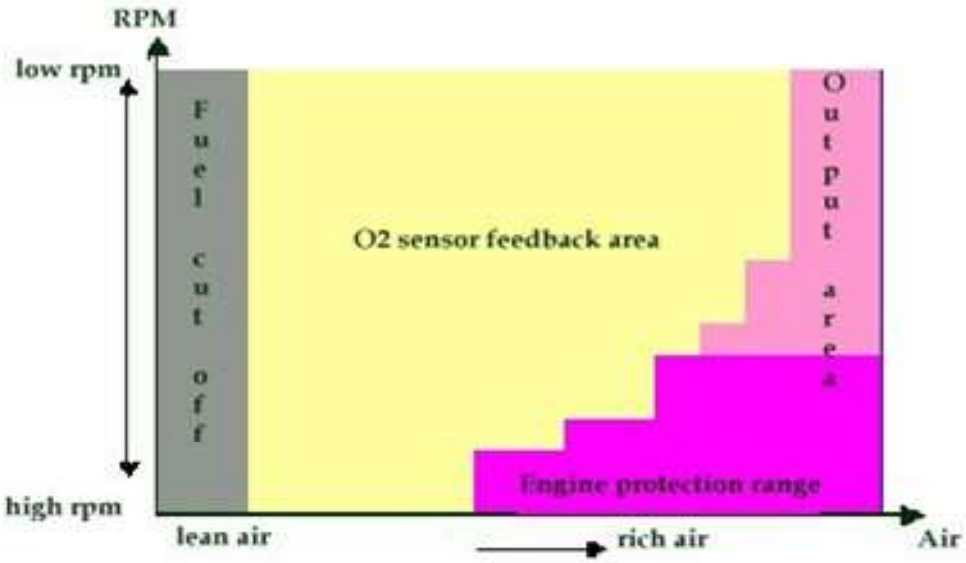
c) Battery voltage correction :

Injector opens by electromagnetic power and closes by spring power, and there is delay time to open injector depend on battery voltage. So, final injection opening time is decided after compensating this injector opening delay time depending on battery voltage.

< Figure 6 : Injector opening >

d) Power area correction : In case of throttle pedal pushing more than 70%, LBT(Leanest fuel for Best Torque) is set at the area of out of emission test mode.

e) Correction for engine protection : Exhaust gas temperature is high in the area of high engine speed and high



air flow, so that engine damage by heat is expected and especially catalyst or oxygen sensor can be damage. In order to prevent this, additional fuel is provided to reduce the temperature by fuel vaporizing. Normally maximum limit of exhaust gas temperature is below 830°C.

f) Fuel correction for electric load or mechanical load operation. : Additional fuel is provided when electric load and mechanical load such as automatic gear shift, air conditioner ON or operation of power steering. There are some cases of engine stall right after automatic gearshift due to much lake of fuel (Lean spike). Therefore this correction is important at cold engine but may not used in warmed-up engine.

Other fuel calculation using two different slop of 1st and 2nd is to calculate exact fuel quantity but I'd like to talk it later.

Among the many fuel corrections as remarked above, sometimes fuel correction by adaptation lead some problems.

Trouble shooting with injection adaptation

1) Problem with too small "additive term" in idle.

In case of this problem is occurred before feedback control and disappeared after feedback control

< Trouble type >

a) Engine is oscillate right after start and stable after feedback control.

b) Big engine oscillation right after start and engine stall.

c) Engine vibration is disappeared after oxygen sensor feedback.

d) Impossible to accelerate right after start and in some case engine rpm is very unstable with oscillation or engine stall after return to idle rpm but it is O.K. after a while.(after feedback control)

< Reason >

If no feedback is performed by oxygen sensor, injection time is totally depend on calculation formula. In this time if injection adaptation is too much minus, problem can be happened due to this minus correction and disappear as soon as oxygen sensor feedback start to correct injection.

< Counteraction >

Too much minus adaptation means that injection is provided to much abnormally. Therefore, check the reason of abnormal fuel supply and delete adaptation value.

As a Reference, some of electric control unit maker limit the adaptation on purpose to prevent above problem. But this can not reduce so much the car to car variation.

a) Check if oil gas coming in via PCV in idle.

This can be happened when too much oil is filled or engine is too hot by bad oil performance due to no oil change on time.

Basically, carmaker should prevent oil from PCV to the engine, yet this can be improved by fill correct amount of oil and exchange oil on time. If it is not improve yet, then use high class oil.

b) Check if canister solenoid(a valve controls amount of fuel gas from canister to the engine) valve opens abnormally. Depending on electric control unit maker, canister solenoid value can be open in idle but with very small opening. Then if this valve opens too much during idle, this makes problem not only due to too much fuel gas but also due to too much "minus adaptation" of injection.

It is difficult to check this valve because in may case, this valve is open at high temperature and close after cooling. The method is to check valve when engine room is hot. Breathe on the valve and check if it air flow

through the valve. If yes then it is wrong one. Do not say it is O.K. after test just one time. As this phenomenon is irregular, please check it several times. But the problem is that this trouble can be happened after valve change. Valve maker must improve this problem and a few vehicles in domestic show this kind of problem.

c) In case of bad tappet opening : If insufficient oil is supplied to the tappet that opens intake valve, intake air is decreased and oxygen sensor detects more fuel compared to air quantity in the cylinder and adaptation can adapt "minus". This case can be happened when oil condition is bad, yet there are some cases that have the problem with car itself.

Thus some engineers have insisted on developing the car with solid tappet instead of hydro tappet.

Counteraction in the field is to use high-class synthetic oil to prevent bubbles in the oil or to increase oil pressure by about 1bar.

d) In case of EGR valve is installed, exhaust gas can go into the engine during idle by leakage. And then if minus adaptation is occurred because of exhaust gas that decrease air quantity in the cylinder and increase fuel relative to air, above mentioned problem can be happened. Yet the problem (engine stall or unstable) will be happened as soon as exhaust gas is coming to the engine before we recognize the problem caused by adaptation. But if there is no action on this problem, another problem caused by adaptation will be occurred.

2) In case of too much "plus" fuel adaptation

There are almost no case that makes driveability problem with too much "plus" adaptation of fuel but emission increase due to much fuel. Emission problem gives big influence emission test mode (FTP75 or LA 4 mode) but no effect to general car workshop or car service center (because test is performed after engine warm-up and after oxygen sensor feedback control start.)

As a reference, If possible I tuned the electric control unit to learn fuel adaptation plus side to avoid above problem.